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THE EFFECTS OF PREMATURE DRILL IN THIRD-GRADE ARITHMETIC

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WHATEVER other connotations the word possesses, "drill" as used in this paper refers to those activities on the part of the teacher which are designed to set up comparatively unvaried practice on the part of the pupil. Drill in the case of the number combinations consists in those teacher-procedures through which the pupil is led to say the appropriate verbal formulas, or to read or to write the corresponding symbols, over and over again without significant change. In the case of computation (as in column addition with whole numbers) drill comprises whatever means the teacher adopts to get the pupil to perform relatively the same operations time after time. As here defined, then, drill relies upon repetition for its effect upon learning.

CRITICAL REVIEW OF PREVIOUS INVESTIGATION ON THE EFFECTS OF DRILL

Research on the effects of drill is now by no means as popular as it was at one time. Experimental interest in the problem began with Thorndike's 1908 study (1)[1], reached its peak in the period 1910 to 1920, and has now considerably subsided. In more recent years the large number of investigations on drill have been less concerned with its effects upon learning than with such related matters as the length of the drill period, the comparative merits of mixed and isolated drill organization, and the like. It is as if the instructional value of drill had been firmly established and now the major problem is how the drill should be administered.

There would seem to be in the experimental literature abundant justification for belief in the vital importance of drill in arithmetic instruction. Without exception investigators have reported that drill, of whatever sort and however administered, improves efficiency. From the outset the consistency of the experimental data has, as it were, blocked off any

[1] The numbers in parenthesis refer to the bibliography at the end of the article, in which the experimental investigations cited are arranged in chronological order.

tendency to question the findings themselves or their meaning for the teaching of arithmetic. On the contrary, the completeness with which they have been accepted is to be seen in the conspicuous place accorded drill in current thought and in school practice. Advertisements of new texts carefully mention the scrupulous attention given the matter of drill provisions. Commissions charged with the selection of text series weigh heavily the success or failure with which competing authors have allotted and distributed drill according to stated criteria. Practice pads and workbooks continue to appear, oftentimes without correlation with textbook development or recommended instructional procedures of their own. All of this clearly involves the assumption that drill is the essential thing. In many a classroom instruction in arithmetic has become virtually synonymous with the administration of drill.

In view of these facts any skepticism concerning the instructional significance of the research on the effects of drill seems almost to constitute an impertinence. Nevertheless, in 1924, Buswell and Judd (20), on page 107 of their ''Summary,'' had the following to say:

''One gets the impression from the reports of the experiments with drill that the investigators have been more concerned with what could be done under specific conditions than with determining the place of drill in the total program of teaching arithmetic.''

Now, this sentence is as true in 1935 as it was eleven years ago. To it may be added a second sentence equally skeptical: that while the experimenters may themselves have been concerned with the results of drill in particular circumstances, the implications of their findings have been by no means restricted to circumstances which correspond with those of their investigations.

At the time this paper was written, sixteen of the nineteen experimental reports on the effects of drill were available for first-hand inspection. These were examined with regard to two important points, namely, (1) the school grades in which the studies were made, and (2) the measures obtained.

(1.) *Grades in which studies were made.*—Of the sixteen investigations referred to above, nine (1, 2, 3, 4, 7, 11, 13, 16, 18) were made in grade V and above,[2] three of them with high-school graduates (1, 2, 4).

[2] An investigation is here classified on the basis of the lowest grade used. Thus, if an investigation was made in grades IV, V, VI, and VII, it is here assigned to the fourth-grade group only.

Four of the remaining seven were made in grade IV (5, 6, 8, 14). The other three (15, 17, 19), made in grade III, were conducted some weeks or months after instruction in the skills upon which drill was given. In all sixteen experiments, therefore, drill followed initial instruction by varying margins—from some weeks to more than ten years.[3] In none of the experiments was a test made of the value of drill as an early step in teaching—as a means of promoting understanding and supplying meaning for that which was to be practiced. On the contrary, the problems of these experiments related to the effectiveness of drill for *improving, fixing, maintaining,* and *rehabilitating* skills which had already been assured by prior instruction. No matter how unmistakably the experiments reveal these virtues in drill, therefore, they do not at all justify many current practices in introducing arithmetic skills and facts—that is, of course, if it be granted that these skills and facts should be intelligible to children.

(2.) *Measures obtained.*—Next the reports were examined with regard to the measures used in these experiments. Invariably these measures have been measures of time, of accuracy, or of both time and accuracy. They are, therefore, measures of *efficiency*: they tell *how well* one performs, but not *how* one performs. The distinction is no mere verbal quibble. Suppose that Johnnie is required to give the sum of 5 and 4. Suppose further that he obtains his answer by thinking, "5, 6, 7, 8, 9." In the typical experiment, records are made of his time (let us say .6 second) and of the correctness of his answer. The fact that he counted to get the sum is disregarded. Suppose now that George secures the same answer of 9 for the combination in the same length of time (.6 second), but that he does so by thinking "5 and 5 are 10, so this is 9." The experimental records for George are identical with those for Johnnie. It is true that Johnnie and George are equal in efficiency, but they are by no means equal in level of performance. Johnnie is a counter; George is capable of a much more advanced type of quantitative thinking. His level of performance is distinctly higher than is Johnnie's.

Now, if growth in arithmetic is conceived to be the development of

[3] The experimental reports which were not available were: 9, 10, and 12. Insofar as these studies are reviewed in the Buswell-Judd "Summary" their general nature agrees with that described for the sixteen available studies. Thus, numbers 10 and 12 were both made in grade V.

expert quantitative thinking,[4] then instructional procedures must be evaluated in terms of children's thought processes. It follows too that measures of performance level are better indexes of arithmetical development than are measures of efficiency. Nevertheless, these measures of performance level have been neglected[5] in the experiments on the effects of drill. It may be conceded that drill increases, fixes, maintains and rehabilitates efficiency. Even so, a more important question remains unanswered—"What contribution, if any, does drill make to raising the level of children's performance in arithmetic, to promoting growth in mature forms of quantitative thinking?" The remainder of this paper is devoted to a brief report of a study which was undertaken expressly to secure at least a partial answer to this question.[6]

THE INVESTIGATION

In the fall of 1932, 63 children entered grade III of the school in which the investigation was conducted. In the two preceding grades these children had been taught the 200 combinations in addition and subtraction through drill. After instruction in counting, the combinations were exposed, a few in each lesson, in random order. A combination, such as 5 + 3, was exhibited, and the answer 8 was supplied by the teacher or by some child who knew it. Individual and group practice followed, in the form of oral, silent, and written exercises—flashcards, games, and the common rapid-exposure devices being employed with a view to establishing mastery over the combinations. If, at a later time, a child did not know a sum or remainder, he was not allowed to find it for himself. Instead, the answer was immediately provided. "Learning" consisted in the repetition of the appropriate verbal formulas. Simple one-step problems then provided use of the combinations so taught.

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[4] It is possible, of course, to entertain quite a different conception of growth in arithmetic. One may, for example, regard arithmetical growth as the accumulation of independent and comparatively unrelated facts and skills. If one holds this latter view of arithmetic (and it seems to be the popular view at present) then the data to be presented here will appear to be of slight consequence, and the arguments to be advanced will appear to be wholly irrelevant.

[5] There is a suggestion of other measures in Smith's study (11). Smith secured some few data on types of errors in computation.

[6] The investigation was made by Miss Charlotte B. Chazal, a graduate student at Duke University, and credit for the data properly belongs to her. A more complete report will be found in her unpublished A.M. thesis bearing the same title as this article, in the Duke University Library, Durham, North Carolina. The thesis is dated 1935.

Outline of the procedure.—Ten days after the children came into grade III, a written test on the 100 addition combinations was given. This test, which will be called Test A, was a group test. The children were urged to be careful to write only correct answers, and were timed to the nearest quarter-minute. Immediately after Test A interviews were held individually with 32 children selected on the basis of their showing on Test A: the nine making the poorest scores, thirteen making average scores, and the ten making the highest scores. Each child was directed to "think out loud" in connection with each of sixteen addition combinations, the ten hardest on Test A and six of average difficulty. This series of interviews will be referred to as Interview I.

Throughout the month which followed (twenty school days) five minutes were taken from the daily arithmetic period for further drill on the addition combinations,[7] so distributed that each combination was presented a total of at least 40 times. At the end of the month the group test on the addition combinations was re-administered as Test B, and Interview II was held with the same 32 children on the same sixteen combinations as were used in Interview I.

Then followed a month in which no special drill was given on the combinations. Finally came Test C and Interview III.

Group test data.—What do the data reveal with regard to the effects of drill? First of all, the data for the written tests (Group Tests A, B, and C) may be examined. On Test A the median time required was seventeen minutes, and the median number of errors was eleven. Both time and errors are excessively high. Even with allowances for the expected influence of the summer's vacation and for the influence from special emphasis on accuracy in the test, the evidence is that drill in grades I and II had hardly succeeded in developing mastery of the combinations.

On Test B, after a month of drill, the median time was lowered from seventeen to eleven minutes, and the median number of errors, from

[7] It is impossible here to give the details of the variations in materials and procedures involved in the drill. It must suffice to say that these materials and procedures were selected with a view to emphasizing *repetition* as the method of learning. The repetitions were silent, written, and oral. The presentations were group and individual, by means of flashcards containing the facts without the answers. The answers were on the reverse of the cards. They were thus accessible to the pupil in individual drill. They were supplied as needed in group drill. The pupils were encouraged always to think, write, or say the sums immediately upon presentation of the facts. They were to establish associations between the facts and the sums by memorizing the verbal formulas.

eleven to four. On Test C, however, after a month without drill, the median time was still further reduced to seven minutes, while the median number of errors remained four, the same as on Test B.

Altogether, it is fair to say that the drill on the combinations in grade III produced results which correspond closely with those reported in the experiments which have been canvassed. It increased *efficiency* as measured in the usual manner: the children after drill could give correct answers to more combinations in less time than before drill. But what about *level of performance*? Did the drill on the combinations make any contribution to improved ways of thinking of the combinations? The interview data contain the answer to this question.

Interview data: categories.—The variety of ways in which a child may secure the sum of an addition combination is very great. For the purposes of this report these many methods have been classified into four major types: "counting," "indirect solution," "guessing," and "immediate recall." A child was said to "count" the combination 3 +4 if he said, "1, 2, 3, . .7," or "3, 4, 5, 6, 7," or if in any other way he dealt with combination, or with either number therein, as so many *ones*. He was said to employ "indirect solution" if he secured his sum for 3 + 4 by saying, "3 and 3 are 6, and this is one more," or "4 and 4 are 8, and this is one less," or "4 and 2 are 6 and 1 is 7," or in any other way made use of smaller numbers as groups. He was said to "guess" if at once upon seeing a combination he announced an incorrect sum and made no attempt to correct it, or, if he did, made still another mistake. He was said to employ "immediate recall" if his response was correctly announced without hesitation.[8]

Data from Interview I.—The data obtained in Interview I consist of the responses of 32 children to sixteen combinations, a total of 512 responses classified according to the four categories just described. They reveal, as no other type of data could, the children's level of performance at the beginning of the term—after two years of drill on the combinations in grades I and II. Of the 512 combinations 22.2 percent were counted; 14.1 percent were indirectly solved; 23.8 percent were guessed; and only 39.5 percent were *known as combinations are supposed to be known* when

[8] It is apparent that the distinction between "guessing" and "immediate recall" is one which resisted reliable classification. Undoubtedly credit was many times given for "immediate recall" when actually the children had "guessed" luckily. This limitation in the technique is freely admitted—the more so since the errors arising therefrom are favorable rather than detrimental to a respectable showing for drill.

taught by drill. (See columns 2 and 5 in Table I.) No one can estimate how many times each of these sixteen combinations had been presented for repetition in grades I and II, but the number must have been very large. Each time one of them was presented, it was expected that the children, upon seeing it or hearing it, would immediately think the sum, and *only the sum*. Such is the assumption underlying the drill procedure —through repetition to associate a given response (as 7) with a given stimulus (as 3 + 4). And yet, in spite of the great amount of practice

TABLE I

FREQUENCY AND PERCENT OF FOUR TYPES OF METHOD USED ON INTERVIEWS

	Frequency by Interview			Percent by Interview		
Method (1)	Int. I (2)	Int. II (3)	Int. III (4)	Int. I (5)	Int. II (6)	Int. III (7)
Counting	116	89	99	22.7%	17.4%	19.3%
Indirect Solution	72	80	65	14.1	15.6	12.7
Guessing	122	93	79	23.8	18.2	15.4
Immediate Recall	202	250	269	39.5	48.5	52.5
Total	512	512	512	100.1%	99.7%	99.9%

in the first two grades, deliberately designed to provide, even to *require*, repetition, at the beginning of grade III only two out of five of these combinations were dealt with in this manner. It is something of a strain on one's credulity to believe that the low level of performance revealed by Interview I was due to vacation losses. It is much more reasonable to believe that drill in the two preceding grades had missed its mark: it had failed to set up the purposed associations, and it left the pupils equipped with the most immature ways of thinking of numbers.

Data from Interview II.—Regardless of the validity of this charge against drill as it applies to the instruction given the two years before in grades I and II, data are at hand from Interview II to test its effectiveness in grade III. Did the month of special drill appreciably raise the level of performance? Counting was found to persist to the extent of 17.4 percent of the total of 512 responses—a reduction of only 5.3 points in percentage. (Columns 2 and 6, Table I.) There was a slight increase in indirect solution, from 14.1 percent to 15.6 percent. Guessing was reduced from 23.8 percent to 18.2 percent; and immediate recall increased 9.2 points, to make 48.8 percent, nearly half, of the total. Part of the gain in immediate recall can probably be ascribed to the restoration of

associations which had "grown rusty" during the summer. Nevertheless, even if one concedes to drill all of the gain made in the month, still its showing is scarcely creditable. Altogether, only 48 more combinations were known as such after drill than before, and counting and guessing combined still contributed more than 70 percent as many responses as did immediate recall.

One should now place these interview data with respect to performance level alongside the efficiency measures obtained in Group Tests A and B. On the group tests there was substantial evidence of the effectiveness of drill—drill improved efficiency. The interview data explain the nature of the improvement: the time and accuracy scores on Test B were better than on Test A, not because the month's drill had materially raised the level of the pupils' performance, not because drill had supplied more mature methods of thinking of the combinations, but because the old methods were, on the second occasion, employed with greater proficiency. The children who on Test A counted, still counted on Test B, but counted more expertly. Those who on Test A relied on indirect solutions made surer use of these methods on Test B, and so on. The month's drill made little contribution to growth in mature forms of quantitative thinking.

Data from Interview III.—The data on Interview III (Columns 4 and 7, Table I) were obtained, it will be recalled, after a month without drill. At that time the children on the average counted two more combinations per hundred than they did at the time of Interview II; they solved approximately three less per hundred and also guessed about three less per hundred; and they recalled immediately nearly four more per hundred. Progress toward automatized associations came therefore at the expense of indirect solution and guessing, though this improvement in performance level was in part balanced by a slight retrogression toward counting.

These measures in Interview III were originally collected to test the degree to which improvement in level of performance effected through drill would persist after cessation of drill. It is not at all clear that they serve this purpose. Whether the gain in known combinations was due to some delayed effect of drill or was due to the elimination of drill and to the introduction of many more kinds of arithmetical experiences, it cannot be said. One explanation is as good as the other. Accordingly, the data are presented only for whatever they may be worth.

Other presentations of interview data.—Thus far, the children's processes have been bulked together regardless of the combinations with which they were used. Chart I represents the situation in a different way. It traces the responses made by given children with particular combinations through the two months of the investigation. Thus, 116 of the 512 combinations were counted on Interview I. One month later, after drill, 69 of the 116 were still counted by the same children who counted them on Interview I; 16 of the 116 were solved, and so on. On Interview III, of the 69 of the original 116 counted combinations, 60 were still being counted, 1 was solved, etc. The form of the chart itself graphically reveals the facts better than they can be expressed in language. Close examination of the chart will serve to support the statements made already with respect to the effects of drill on performance level. This is, of course, inevitable, for the data assembled in Chart I are the same basically as those presented in a different form in Table I.

One last type of record pictures the effects of drill in the case of four selected children. Space permits only an explanation of the manner in which the charts are to be read. Chart II shows what happened in the case of a counter. Her methods with the 16 combinations at the time of Interview I appear in the second column. Her responses to the same combinations on Interviews II and III follow in the last two columns. At the upper right-hand corner are entered her time and accuracy scores on the three group tests, A, B, and C. The record for this girl shows that drill only made her a more efficient counter. (The phrase "Same (17)" in the first line of the chart means that the girl secured her sum (17, in this case) by the same procedure as that used in the interview immediately preceding.)

Chart III illustrates the persistence of indirect solution in spite of drill designed to stop it. Chart IV shows the slight effects of drill upon a child who could get her sums only by guessing. Chart V is that of a child who already knew the combinations when he entered the first grade.

It is unfortunate that these charts cannot be here made the objects of detailed interpretation; they would well repay the space required. No other data which have been presented reveal so clearly the inadequacy of drill as a means of improving quantitative thinking. Since space limitations forbid, this detailed study can only be commended to the reader to make for himself.

CONCLUSION

To summarize, the data collected in this investigation seem to warrant several inferences. First, drill, as it was administered in this study, does not guarantee that children will be able immediately to recall combinations as such. The reason lies in the fact that drill as given by the teachers does not necessarily lead to repetition on the part of pupils. Second, in spite of long-continued drill children tend to maintain the use of whatever procedures they have found to satisfy their number needs. Third, drill makes little, if any, contribution to growth in quantitative thinking by supplying maturer ways of dealing with numbers.

The statement of these conclusions in no way implies that drill has no place in arithmetic. The contrary is the fact: drill is exceedingly valuable for increasing, fixing, maintaining, and rehabilitating efficiency otherwise developed. Nevertheless, these conclusions do particularize the things which drill will *not* do. To be more effective[9] drill must be preceded by sound instruction. This fact, obvious enough upon second thought, should lead to a change in research interest in arithmetic. It should encourage the more vigorous study of the problems of learning and of initial instruction, even if this change in interest should lessen somewhat the extraordinary attention now given to drill. Learning, *not drill,* is the important question in arithmetic.

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[9] That is, of course, on the assumption again that children shall see sense in what they learn. It all depends upon one's conception of arithmetic ability. If the pupil knows arithmetic when he has a memoriter mastery of hundreds of isolated facts, then perhaps he had best learn those facts by brute memorization. If, on the other hand, he knows arithmetic only when he can *use* intelligently what he has learned, then he had best make use of his intelligence in learning the facts. In the light of the former conception, drill (repetition) is adequate for instruction. In the light of the latter conception, drill (repetition) is grossly inadequate. The nature of its shortcomings has been outlined above.

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Footnote: This paper was accepted for publication in this journal some months before the appearance of McConnell's important study ("Discovery versus Authoritative Identification in the Learning of Children," University of Iowa Studies in Education, IX, No. 5; September, 1934). McConnell's problem closely resembled that investigated by Miss Chazal, a fact which will certainly lead the interested reader to consult the McConnell report. At first glance the results obtained in the two studies may seem to be wholly inconsistent. Such is not actually the case. Interpretation depends, in both studies, on the view that is held of the *purposes* of arithmetic instruction. On this account the Chazal study is published in 1935 without change as it was written in 1934. However, the McConnell reference should certainly be included in the bibliography of 20 items immediately above. W. A. B.